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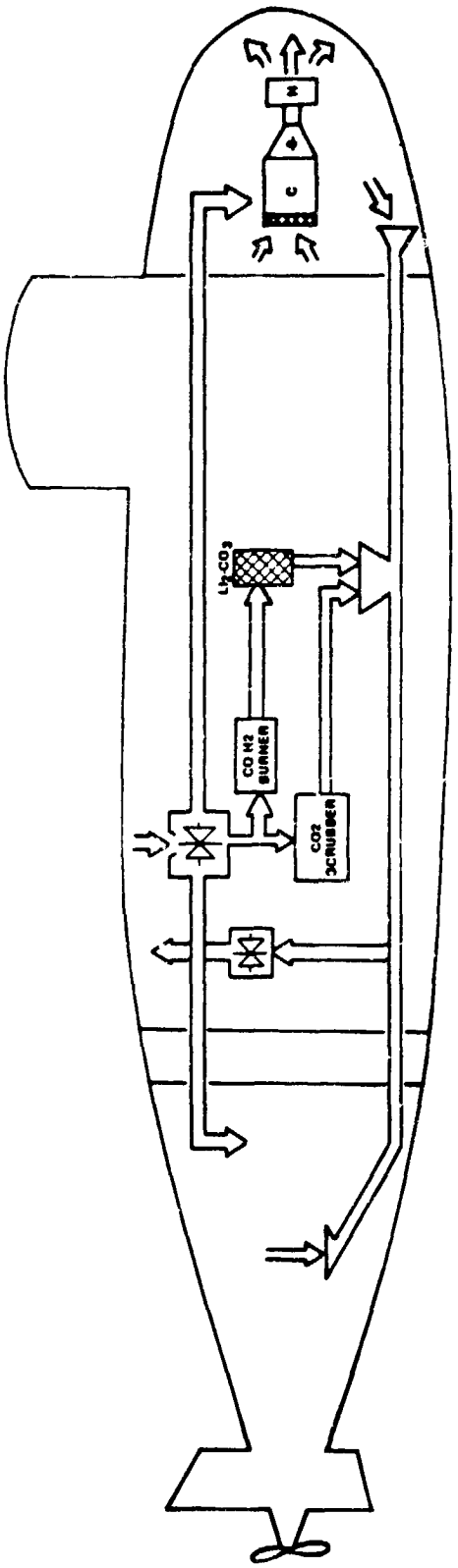


VENTILATION FLOW — SUBMERGED

I. VENTILATION SYSTEM

WHEN THE SUBMARINE IS SUBMERGED, THE VENTILATION SYSTEM PROVIDES A CONDITIONED ATMOSPHERE IN THE SHIP WITH COMPLETE ISOLATION FROM THE OUTSIDE. A CONDITIONED ATMOSPHERE INCLUDES NOT ONLY FILTRATION AND TEMPERATURE AND HUMIDITY CONTROL, BUT ALSO AIR PURIFICATION (REMOVAL OF POTENTIALLY HARMFUL QUANTITIES OF IMPURITIES AND COMTAMINANTS) AND REVITALIZATION (ADDITION OF VITAL LIFE SUPPORT OXYGEN). THIS IS THE NORMAL MODE OF OPERATION OF THE VENTILATION SYSTEM.

THE REMAINING MODES EXCHANGE AIR BETWEEN THE SHIP'S ATMOSPHERE AND THE OUTSIDE AIR.

CARBON DIOXIDE REMOVAL SYSTEM

CARBON DIOXIDE REMOVAL PLANTS PREVENT CARBON DIOXIDE IN THE SHIP'S ATMOSPHERE FROM INCREASING TO AN UNSATISFACTORY LEVEL DURING SUBMERGED OPERATIONS. THIS IS NECESSARY SINCE THE SHIP'S PERSONNEL ARE CONTINUALLY EXPIRING CARBON DIOXIDE TO THE SHIP'S ATMOSPHERE.

BLOWERS SEND EXHAUST AIR TO THE INLETS OF THE CARBON DIOXIDE REMOVAL SYSTEM PLANTS WHEN THE SHIP IS SUBMERGED. THIS PLANT BATHES THE AIR IN A CHEMICAL SOLUTION WHICH HAS AN AFFINITY FOR CARBON DIOXIDE. MOST OF THE CARBON DIOXIDE REMAINS IN THE CHEMICAL SOLUTION, AND THE AIR IS RETURNED TO THE SPACE RELATIVELY FREE OF CARBON DIOXIDE. THE PURIFIED AIR FROM THE CARBON DIOXIDE REMOVAL PLANTS IS DISCHARGED INTO THE INLET OF A VENTILATION

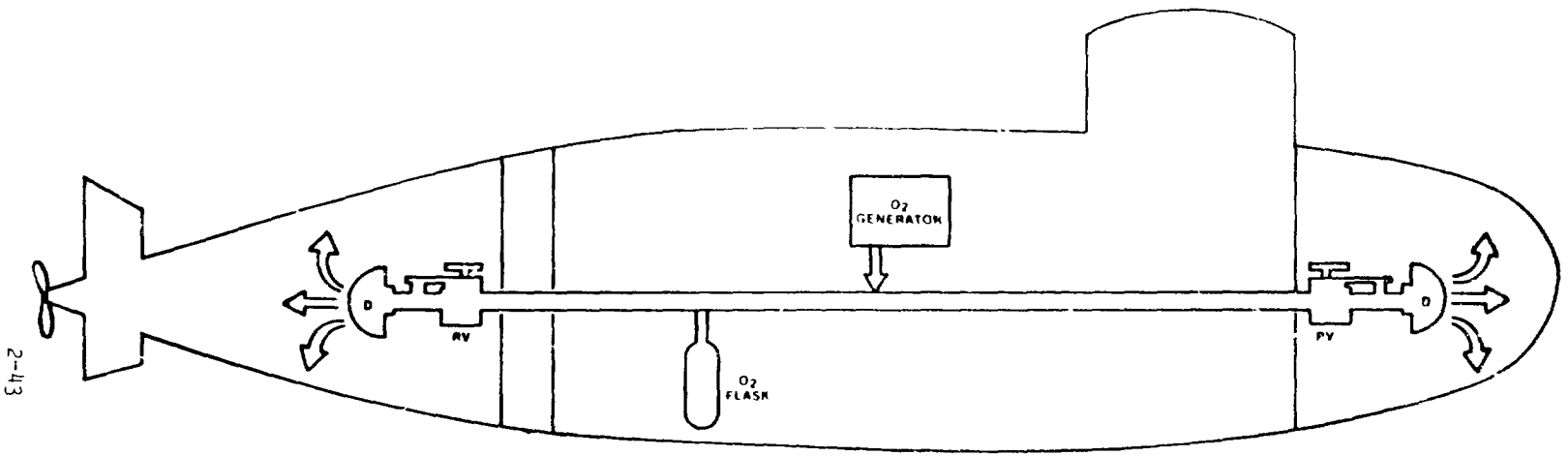
EXHAUST TERMINAL AND RETURNED TO THE SHIP'S VENTILATION SUPPLY HEADER WHERE IT IS DISPERSED THROUGHOUT THE SHIP.

CO-H2 BURNERS

THE CHEMICAL REACTION WHICH TAKES PLACE WITHIN THE CELLS OF THE MAIN STORAGE BATTERY DURING CHARGE AND DISCHARGE, PRODUCES HYDROGEN GAS WHICH IS DISPERSED INTO THE SUBMARINE ATMOSPHERE BY THE VENTILATION SYSTEM. CARBON MONOXIDE AND HYDROCARBONS FROM VARIOUS SOURCES ARE ALSO PRODUCED IN THE SHIP AND MUST BE CONTROLLED AT ACCEPTABLE LEVELS TO PREVENT EXCESSIVE BUILDUPS IN THE SHIP'S ATMOSPHERE. THE FUNCTION OF THE CO-H2 BURNERS IS TO REMOVE THESE CONSTITUENTS FROM THE ATMOSPHERE. THE VENTILATION SYSTEM SUPPLIES A REPRESENTATIVE MIXTURE OF AIR FROM THE SHIP'S EXHAUST HEADER TO THE INLET OF THE CO-H2 BURNERS. THE AIR ENTERS EACH UNIT WHERE IT IS HEATED AND, BY CATALYTIC ACTION, MOST OF THE HYDROGEN, HYDROCARBONS, AND CARBON MONOXIDE ARE BURNED. UNFORTUNATELY, SOME HYDROCARBONS WHEN BURNED PRODUCE BY-PRODUCTS WHICH ARE THEMSELVES TOXIC. THE DISCHARGE OF THE CO-H2 BURNER IS PASSED THROUGH A LITHIUM CARBONATE FILTER DESIGNED TO REMOVE THESE BY-PRODUCTS. THE AIR IS THEN DISCHARGED INTO A VENTILATION EXHAUST TERMINAL WHREE IT IS RETURNED TO THE VENTILATION SUPPLY HEADER FOR DISTRIBUTION THROUGHOUT THE SHIP.

OXYGEN SYSTEM

TO MAINTAIN THE OXYGEN CONTENT OF THE SHIP'S ATMOSHPERE AT THE PROPER LEVEL TO SUPPORT HUMAN LIFE DURING SUBMERGED OPERATIONS, OXYGEN IS PRODUCED BY TWO OXYGEN GENERATORS AND A CHLORATE CANDLE FURNACE. OXYGEN MAY BE BLED FROM STORAGE BANKS INTO THE SHIP FOR DILUTION AND DISPERSAL THROUGHOUT THE SHIP.



OXYGEN SYSTEM

II. OXYGEN SYSTEM

STANDARD DESIGN PRACTICE CALLS FOR A NORMAL SYSTEM DESIGN OXYGEN FLOW RATE OF 1.0 SCFH PER MAN. THE PRIMARY O2 SYSTEM IS CAPABLE OF PROVIDING THIS DESIGN FLOW AS A MINIMUM FOR THE DURATION OF THE MISSION (90 DAYS). PEAK O2 REQUIREMENTS MAY BE AS MUCH AS 1.65 SCFH PER MAN FOR LIMITED PERIODS OF GREATER CREW ACTIVITY.

AN O2 BACKUP SYSTEM IS PROVIDED WHICH IS CAPABLE OF PROVIDING NORMAL O2 REQUIREMENTS OV THE CREW OVER A TEN DAY PERIOD OF SUBMERGED OPERATION.

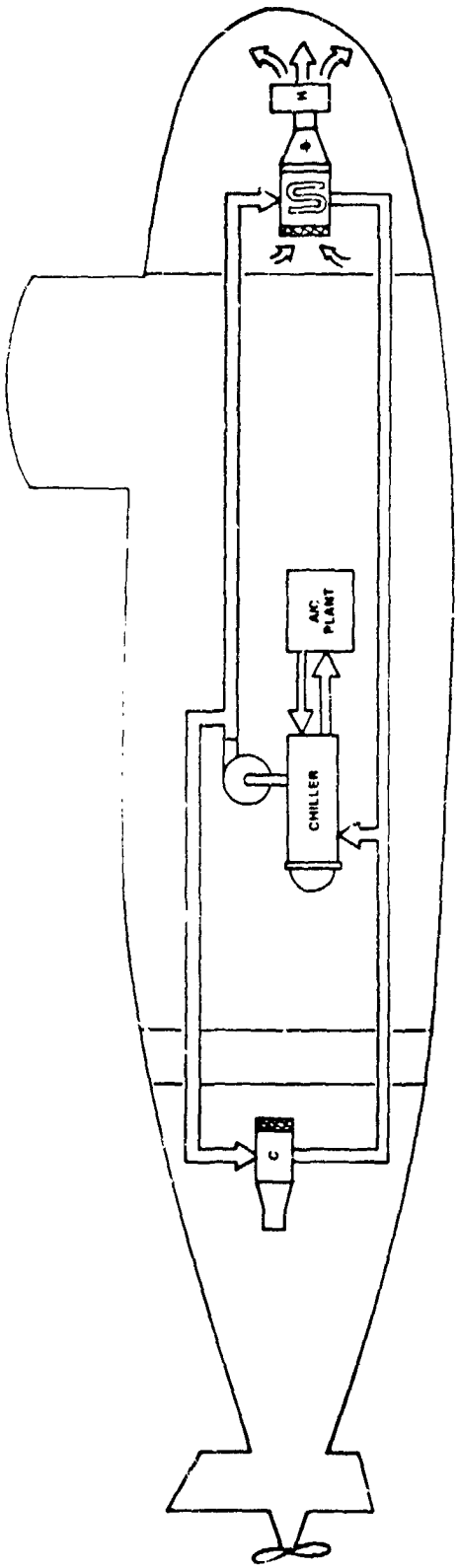
IN ADDITION, AN EMERGENCY O2 SYSTEM IS CAPABLE OF PROVIDING NORMAL O2 REQUIREMENTS OVER SHORTER PERIODS OF TIME.

THE PRIMARY SOURCE OF OXYGEN ON A NUCLEAR SUBMARINE IS AN ELECTROLYTIC OXYGEN GENERATOR WHICH SUPPLIES 3000-PSI OXYGEN TO CHARGE OXYGEN STORAGE FLASKS.

OXYGEN IS NORMALLY DISCHARGED DIRECTLY TO THE SHIP'S ATMOSPHERE THROUGH PRESSURE-REDUCING VALVES AND DIFFUSERS. THE OXYGEN FLASKS ARE CHARGED FROM SHORE AT THE START OF A PATROL AND ARE KEPT FULLY CHARGED BY THE OXYGEN GENERATOR TO PROVIDE SIX DAYS' RESERVE SUPPLY IN THE EVENT OF O2 GENERATOR FAILURE.

THE OXYGEN GENERATOR PRODUCES O2 BY THE ELECTROLYSIS OF DEMMERALIZED WATER USING ELECTROLYTIC CELLS, DISPELLING THE HYDROGEN OVERBOARD. A POTASSIUM HYDROXIDE SOLUTION TO PROVIDE CONDUCTIVITY IS USED AS THE ELECTROLYTIC SOLUTION.

CHLORATE CANDLES ARE AVAILABLE FOR A BACKUP SYSTEM AND THE STORED OXYGEN IS CLASSIFIED AS AN EMERGENCY SUPPLY.



CHILLED WATER SYSTEM

III. AIR CONDITIONING

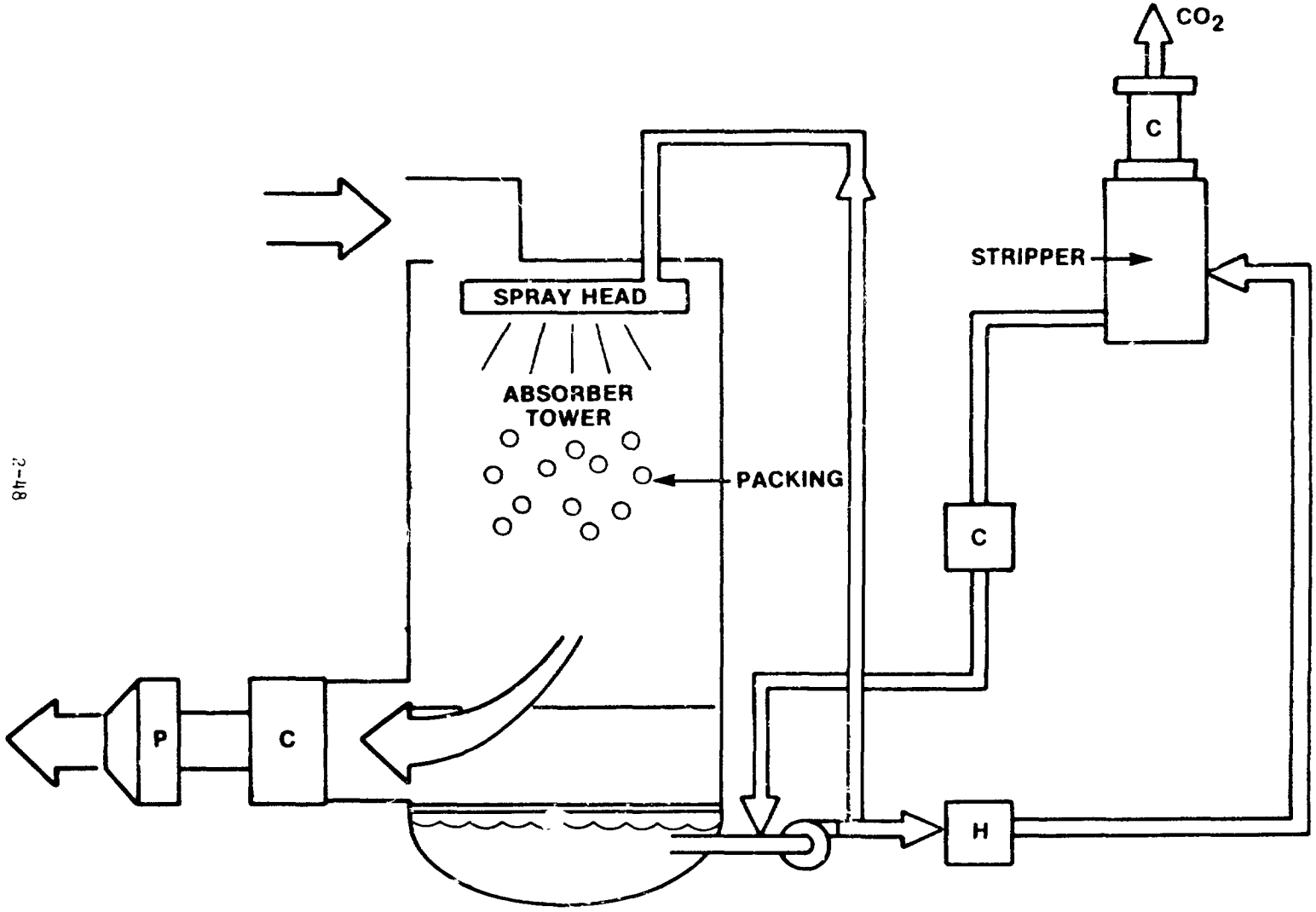
AN AIR CONDITIONING SYSTEM PROVIDES AND MAINTAINS A COOLED AND DEHUMIFIED ATMOSPHERE FOR EQUIPMENT AND PERSONNEL ON THE SHIP. THE SYSTEM CONSISTS OF R-114 AIR CONDITIONING UNITS, A CHILLED WATER SYSTEM, AND AN AIR CONDITIONING CONTROL SYSTEM.

THE R-114 AIR CONDITIONING PLANTS EMPLOY DICHLOROTETRAFLUORETHANE (R-114) AS A REFRIGERANT. THE THERMODYNAMIC PROPERTIES OF R-114 MAKE IT IDEAL AS A HEAT TRANSFER MEDIUM. R-114 IS ALSO CHEMICALLY STABLE, NON-CORROSIVE, AND NON-TOXIC. THE R-114 VAPOR COMPRESSION UNITS REMOVE HEAT PICKED UP THE CHILLED WATER SYSTEM FROM EQUIPMENT AND LIVING SPACES AND TRANSFERS THE HEAT TO SEAWATER.

A CHILLED WATER SYSTEM CIRCULATES WATER CHILLED BY THE REFRIGERANT TO COOLING COILS AND HEAT EXCHANGERS FOR AIR CONDITIONING AND EQUIPMENT COOLING. VENTILATION FANS FORCE AIR PAST THE COOLING COILS WHERE THE AIR IS COOLED AND DEHUMIDIFIED. HEAT IS TRANSFERRED FROM THE AIR TO THE CHILLED WATER IN THE COILS. OTHER COMPONENTS ARE COOLED BY CHILLED WATER FLOWING THROUGH THEIR HEAT EXCHANGERS. THE WARM CHILLED WATER RETURNS TO THE AIR CONDITIONING UNIT CHILLERS, WHRE ITS HEAT IS TRANSFERRED TO THE REFRIGERANT AND ULTIMATELY TO THE SEAWATER.

THE AIR CONDITIONING CONTROL SYSTEM SENSES TEMPERATURE AND HUMIDITY IN EQUIPMENT AND LIVING SPACES. THE SENSING DEVICES ARE PNEUMATICALLY OPERATED THERMOSTATS AND HUMIDISTATS

WHICH SENSE CHANGES IN TEMPERATURE AND HUMIDITY AND CONVERT THESE SIGNALS INTO AIR SIGNALS. RESULTING AIR SIGNALS ARE COMPARED IN LOGIC CIRCUITS WHERE THE STRONGEST DEMAND ACTUATES THE FINAL CONTROL ELEMENT TO SATISFY COOLING, DEHUMIDIFICATION, OR HUMIDIFICATION REQUIREMENTS.



CO_2 SCRUBBER

IV. CARBON MONOXIDE REMOVAL

STANDARD PRACTICE IN SUBMARINE DESIGN CALLS FOR MAINTAINING CO_2 LEVELS AT OR BELOW 0.5%.

A PROVISION FOR BACKUP AND EMERGENCY CO_2 REMOVAL SPECIFIES A SUPPLY OF LITHIUM HYDROXIDE (LIOH).

THE PRIMARY SYSTEM FOR CO_2 REMOVAL IS THE MONETHANOL AMINE (MEA) SCRUBBER. GENERALLY, EACH SUBMARINE WILL HAVE TWO OF THESE UNITS. THE PROCESS FOR CO_2 REMOVAL IS ONE OF ABSORPTION. THE ABSORPTION AGENT IS MONETHANOLAMINE (AMINE OR MEA). THE LATEST SCRUBBERS CAN REMOVE THE INLET AIR CO_2 CONCENTRATION OF 1.5% TO ABOUT 0.2% AT THE OUTLET, AT A RATE OF 170 CUBIC FEET PER MINUTE. THE TWO SCRUBBERS TAKE SUCTION ON THE SHIP'S AIR AND ABSORB THE CO_2 IN AN AMINE SOLUTION. THE CO_2 IS REMOVED FROM THE AMINE SOLUTION AND DISCHARGED OVERBOARD. THE AMINE SOLUTION IS RE-USED IN THE SCRUBBERS.

THE CO_2 REMOVAL PLANT CONTAINS FIVE INTERRELATED SYSTEMS: AIR CIRCULATION SYSTEM, MONOETHANOLAMINE (MEA OR AMINE) CIRCULATING SYSTEM, CARBON DIOXIDE REMOVAL REMOVAL SYSTEM, AIR-CONDITIONING CHILLED WATER SYSTEM, AND AN ELECTRICAL AND INSTRUMENTATION SYSTEM.

THE AIR CIRCULATION SYSTEM FORCES ATMOSPHERIC AIR INTO THE TOWER AND DOWN THROUGH PACKING. AS THE AIR PASSES THROUGH THE TOWER, THE CO_2 IS ABSORBED BY A COOL AMINE SOLUTION, WHICH IS SPRAYED OVER THE PACKING. AT THE BOTTOM OF TOWER, A FILTER FUNNEL

LEADS THE PURGED AIR TO AN AIR PURIFIER WHERE THE AIR IS WASHED IN A SOLUTION OF FRESH WATER AND SODIUM BISULPHATE TO REMOVE THE ODOR OF AMMONIA.

THE AMINE IS CONTINUOUSLY RECYCLED THROUGH THE ABSORBER TOWER, ENTERING THE TOP THROUGH SPRAY NOZZLES, FLOWS DOWN THROUGH THE PACKING, COLLECTS IN THE BOTTOM, AND RETURNS TO THE SPRAY HEAD VIA A RECYCLING PUMP.

CO_2 IS REMOVED FROM THE AMINE BY HEATING AND STRIPPING. A SMALL AMOUNT OF THE CO_2 SATURATED AMINE IS DRAWN FROM THE BOTTOM OF THE TOWER AND ENTERS A HEAT EXCHANGER WHERE IT IS PREHEATED BY HOT, LEAN (STRIPPED) AMINE RETURNING FROM THE STRIPPER TOWER.

IN THE STRIPPER TOWER, AMINE ENTERS THE MIDDLE SECTION THROUGH SPRAY NOZZLES WHERE IT SEPARATES INTO MOISTURE AND AMINE VAPOR AND CO_2 GAS. THE AMINE VAPORS CONDENSE ON RINGS BENEATH SPRAY NOZZLES AND FLOWS DOWN TO THE BOTTOM SECTION. THE CO_2 AND A SMALL AMOUNT OF MOISTURE RISE TO THE TOP SECTION.

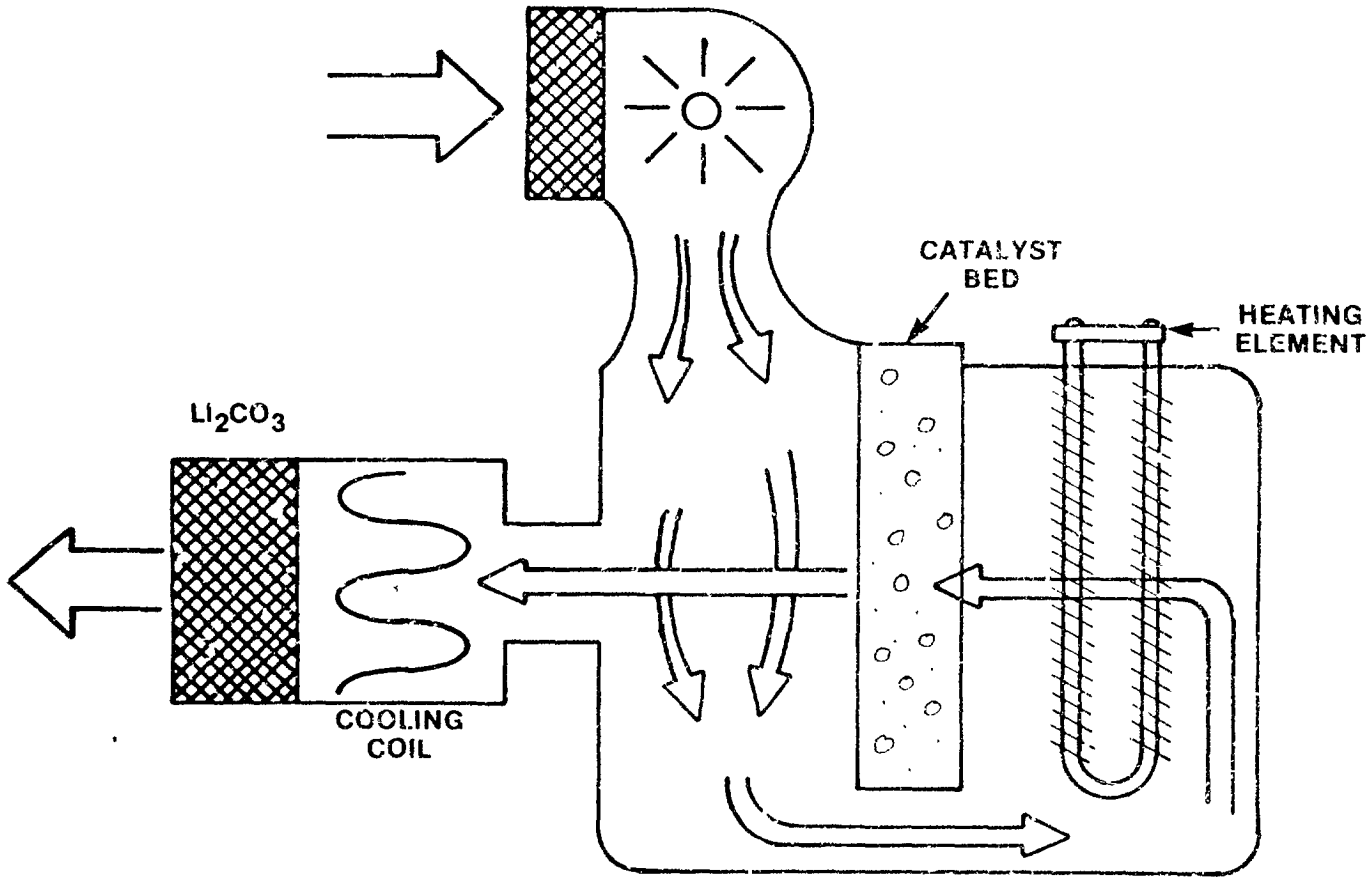
IN THE TOP SECTION, FRESH WATER TUBES CONDENSE THE MOISTURE, AND THE CO_2 PASSES TO A WATER SEPARATOR WHERE THE REMAINING MOISTURE IS REMOVED.

AFTER COMPRESSION, THE CO_2 FROM BOTH SCRUBBERS IS DISCHARGED OVERBOARD VIA SEA WATER PIPING. THE AIR-CONDITIONING CHILLED WATER COOLING SYSTEM SUPLIES WATER TO THE COOLER SECTION OF THE AIR PURIFIER, THE CO_2 COOLER, AND AN AMINE COOLER.

THE ELECTRICAL AND INSTRUMENTATION SYSTEMS CONTROL ALL ASPECTS OF THE CO_2 SCRUBBER.

CANISTERS ARE USED FOR BACKUP AND EMERGENCY CO_2 REMOVAL. IN THE BACKUP METHOD, AIR IS VENTILATED THROUGH CANISTERS OF LIOH BY A FAN AND FILTER ARRANGEMENT.

IN THE EMERGENCY MODE, THE CANISTERS ARE OPENED AND THE LIOH SPREAD ON THE FLOOR OR OTHER HORIZONTAL SURFACES WHERE NATURAL DIFFUSION ACTS TO CONTACT THE CO_2 WITH THE LIOH.



$CO\text{-}H_2$ BURNER

V. CARBON MONOXIDE AND HYDROGEN REMOVAL

CARBON MONOXIDE (CO) AND HYDROGEN (H_2) CONCENTRATIONS AND HYDROGEN CONTAMINANTS ARE MAINTAINED WITHIN ESTABLISHED LIMITS BY MEANS OF THE SHIPS AIR REVITALIATION SYSTEM.

CARBON MONOXIDE (CO) IS PRODUCED BY THE SMOKING OF TOBACCO, COOKING (PARTICULARLY WHEN FOOD IS BURNED), AND OVERHEATING OF ELECTRICAL EQUIPMENT. A SMALL AMOUNT OF CO IS ALSO GIVEN OFF BY THE HUMAN BODY. THE AMOUNT OF CO A PERSON CAN TOLERATE IS DEPENDENT ON THE LENGTH OF EXPOSURE. THE MAXIMUM CONCENTRATION FOR 90 DAYS CONTINUOUS EXPOSURE HAS BEEN ESTABLISHED AS 25 PARTS PER MILLION.

THE MAJOR SOURCE OF HYDROGEN (H2) IS THE SHIP'S BATTERY, WHICH GIVES OFF HYDROGEN DURING CHARGING. OTHER SOURCES ARE POSSIBLE LEAKAGE OF THE HYDROGEN BOTTLES, THE OXYGEN GENERATOR, AND THE SANITARY TANK PIPING.

NUMEROUS TYPES OF HYDROCARBONS ARE PRODUCED FROM MATERIALS SUCH AS DIESEL FUEL OIL, CLEANING SOLVENTS, LUBE OILS, COOKING FATS, CIGARETTE LIGHTER FLUID, PAINTS, AND MANY OTHER SOURCES.

DURING SUBMERGED OPERATIONS, CO-H_2 BURNERS REMOVE CARBON MONOXIDE AND HYDROGEN FROM THE SHIP'S ATMOSPHERE BY OXIDIZING CARBON MONOXIDE TO CO_2, HYDROGEN TO WATER VAPOR AND HYDROCARBONS TO CO_2 AND WATER VAPOR.

THE PURIFIED AIR IS RETURNED TO THE SHIP'S ATMOSPHERE. THE CO_2 IS REMOVED BY THE CO_2 SCRUBBERS AND THE WATER VAPOR IS CONDENSED BY THE AIR CONDITIONING COOLING COILS.

IN THE CO-H_2 BURNERS, A FAN DRAWS COMPARTMENT AIR INTO THE INLET DUCT THROUGH A FILTER AND INTO THE INLET SIDE OF A HEAT EXCHANGER WHERE THE AIR IS PREHEATED TO THE FIRST OF THREE LEVELS. THE AIR IS HEATED TO A SECOND LEVEL BY PASSING OVER A BANK OF ELECTRIC HEATERS, AND TO THE THIRD AND FINAL LEVEL BY BURNING HYDROGEN IN THE CATALYST BED AT A TEMPERATURE OF 600°F. THE HEAT IS PARTIALLY REMOVED FROM THE AIR STREAM AS IT PASSES THROUGH THE OUTLET SIDE OF THE MAIN HEAT EXCHANGER. THIS HEAT IS TRANSFERRED TO THE AIR ENTERING THE INLET DUCT OF THE HEAT EXCHANGER. BECAUSE THE HEAT EXCHANGER CANNOT REMOVE ALL THE HEAT FROM THE OUTGOING AIR, AN AFTERCOOLING COIL IS USED TO COOL THE AIR TO THE REQUIRED EXIT TEMPERATURE BEFORE IT IS DISCHARGED FROM THE UNIT.

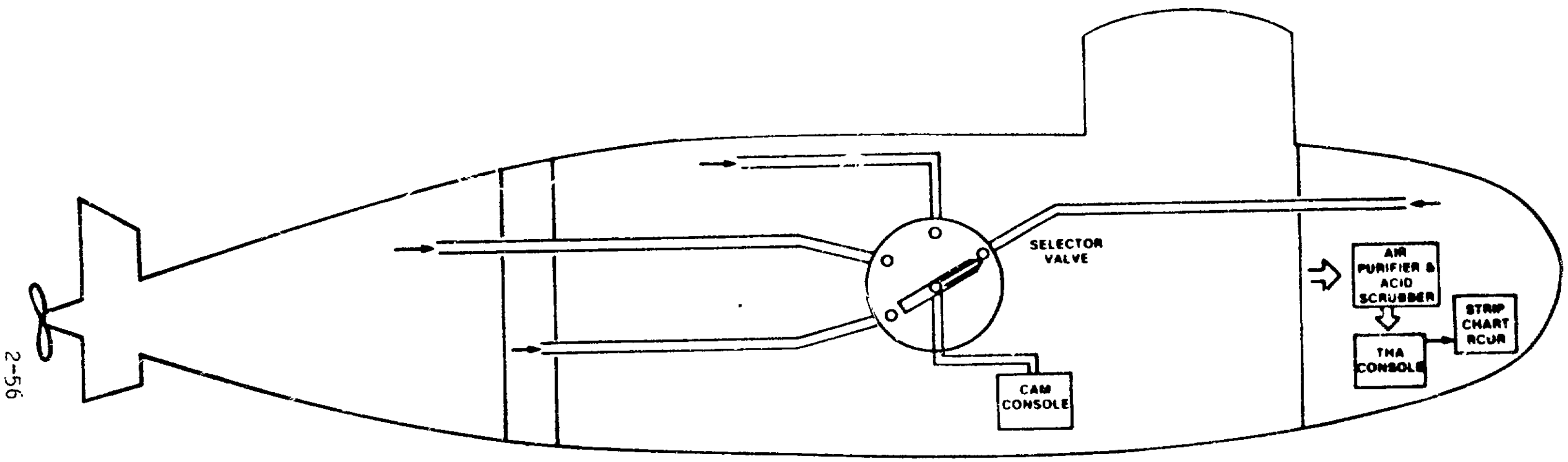
IT IS IN THE CATALYST CHARCOAL BED, CONSISTING OF 10% LIOH AND 90% HOPCALITE THAT THE CHEMICAL REACTIONS TAKE PLACE PRODUCING THE CO_2 AND H_2O. THE INCREASING AIR TEMP IS SUFFICIENT TO START THE REACTIONS. THE CHARCOAL BED IS CHANGED PERIODICALLY.

SOME PROBLEMS OCCUR WITH THE DECOMPOSITION OF HALOCARBONS WHICH MAY RESULT IN THE PRODUCTION OF ACIDE GASSES. THE OUTLET AIR IS THUS PASSED THROUGH A $LiCO_3$ FILTER WHICH DECOMPOSES MOST OF THE HALOCARBONS. THE EFFICIENCY OF THE FILTER HOWEVER IS LESS THAN 100%.

VI. OTHER CONTAMINANT REMOVAL SYSTEMS

AIR PROCESSING UTILIZING ELECTROSTATIC PRECIPITATORS IS THE PRINCIPLE METHOD FOR REMOVING PARTICULATES (AEROSOLS).

ACTIVATED CHARCOAL BEDS AND HIGH EFFICIENCY FILTERS ARE ALSO IN USE THROUGHOUT THE SHIP'S VENTILATION SYSTEMS.

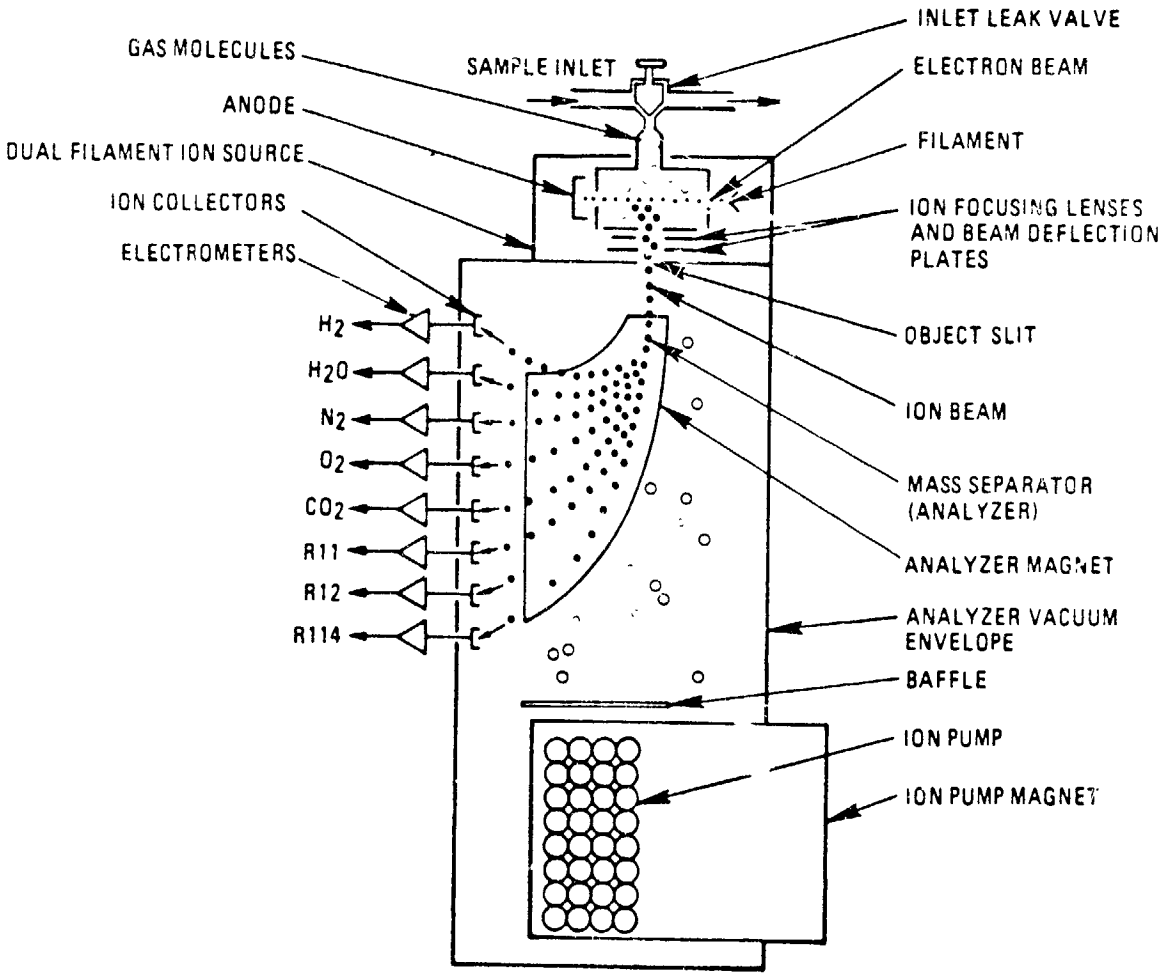


ATMOSPHERE ANALYZING SYSTEM

VII. ATMOSPHERE MONITORING SYSTEMS

THE ATMOSPHERE ANALYZER SYSTEMS AND THE TOTAL HYDROCARBON ANALYZER COMPRISE THE PRIMARY ATMOSPHERE MONITORING SYSTEMS FOR THE SHIP. THE ATMOSPHERE MONITORING EQUIPMENT, TERMED THE CENTRAL ATMOSPHERE MONITORING SYSTEM (CAMS) ANALYZES REPRESENTATIVE AIR SAMPLES FROM VARIOUS LOCATINS WITHIN THE SHIP THROUGH A SAMPLE SELECTOR VALVE. IN ADDITION, THE TOTAL HYDROCARBON ANALYZER IS USED TO EVALUATE THE EFFECTIVENESS OF THE INSTALLED VENTILATION SYSTEM CARBON FILTERS. THE LOCATION AND IDENTIFICATION OF ATMOSPHERIC CONTAMINANT CONCENTRATIONS BY THESE SYSTEMS IS THE BASIS FOR THE CORRECTIVE ACTION WHICH MUST BE TAKEN TO SOLVE THE CONTAMINANT PROBLEM IN THE SHIP'S ATMOSPHERE SUCH AS THE PROPER USE OF THE SCRUBBERS, BURNERS, AND O_2 GENERATORS. MANIPULATION OF THE VENTILATION SYSTEM IS ALSO NECESSARY TO CONTROL CONTAMINANTS. FOR INSTANCE, EMERGENCY EVACUATION OF A COMPARTMENT WITH SPECIAL BLOWERS MAY BE REQUIRED TO REMOVE HIGH CONCENTRATIONS OF CONTAMINANTS. PORTABLE ANALYTICAL MONITORING EQUIPMENT IS ALSO AVAILABLE.

THE ABILITY TO CONTROL SUBMARINE ATMOSPHERE QUALITY RESTS ON PRECISE MONITORING OF ATMOSPHERIC CONSTITUENTS. PROPER USE OF THE SCRUBBERS, BURNERS, AND OXYGEN GENERATORS IS GOVERNED BY CONCENTRATION MEASUREMENTS OF BOTH VITAL AND HARMFUL GASES IN THE SHIPS ATMOSPHERE. THIS INFORMATION IS OBTAINED FROM THE SHIPS CAMS, TOTAL HYDROCARBON ANALYSIS (THA), AND PORTABLE ANALYTICAL MONITORING EQUIPMENT.



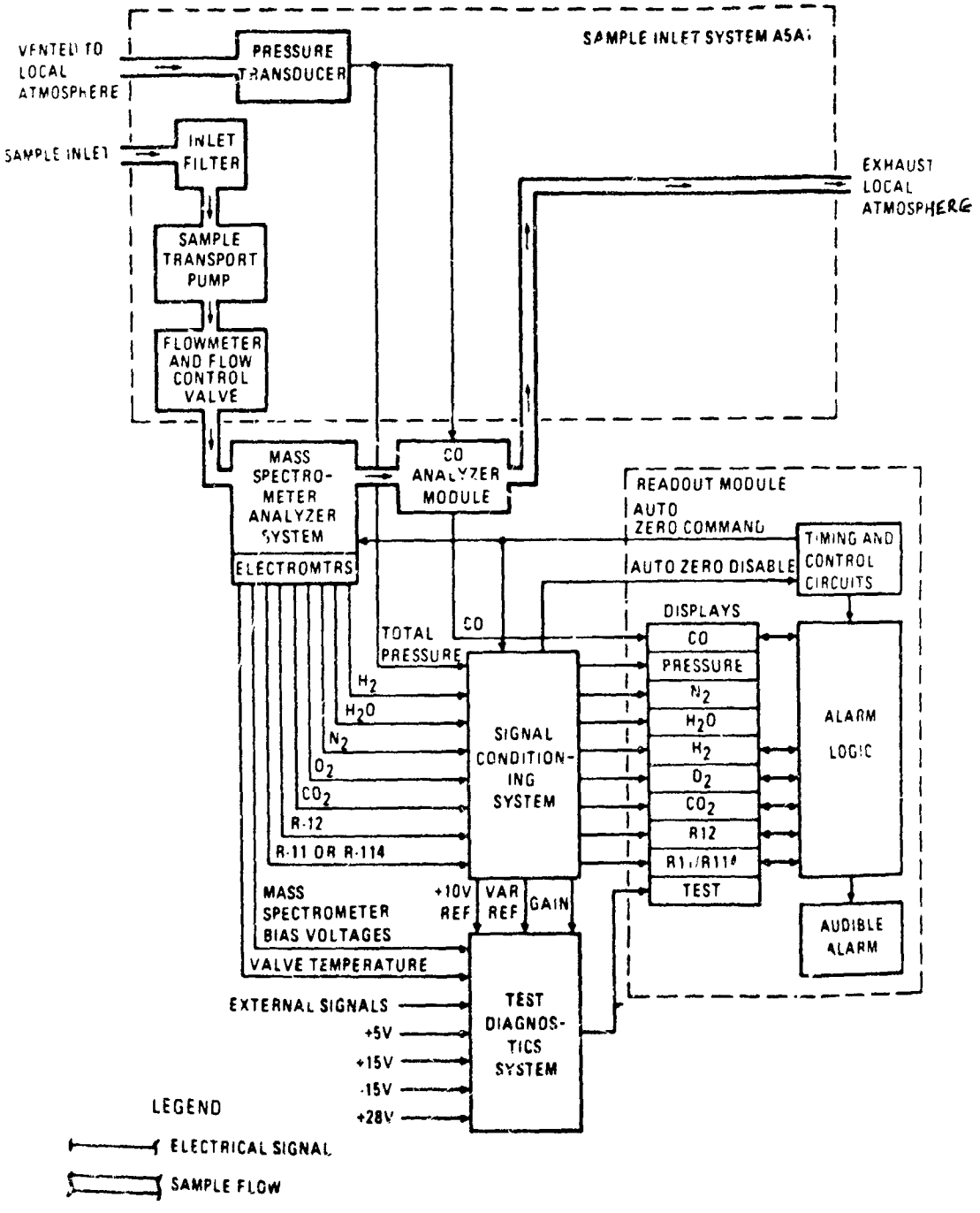
CAMS MK I
MASS SPECTROMETER ANALYZER

THE CAMS MONITORS AND MEASURES THE FOLLOWING CONTAMINANTS AND COMPONENTS OF THE SHIPS ATMOSPHERE:

(1) CARBON MONOXIDE (CO)
(2) HYDROGEN (H_2)
(3) OXYGEN (O_2)
(4) CARBON DIOXIDE (CO_2)
(5) NITROGEN (N_2)
(6) WATER VAPOR (H_2O)
(7) FREON 12
(8) FREON 11 OR 114, AS SELECTED

CAMS, UTILIZING THE PRINCIPLES OF MASS SPECTROSCOPY AND NON-DISPERSIVE INFRARED TO ANALYZE THE SUBMARINE'S ATMOSPHERE CONSTITUENTS, IS THE RESULT OF A NUMBER OF EXPERIMENTS WITH SUBMARINES AND THE ADVANCES IN MASS SPECTROMETRY IN THE LATE 1960'S, LARGELY BECAUSE OF THE SPACE PROGRAM.

SUBMARINES HAVE APPROXIMATELY A DOZEN LOCATIONS FROM WHICH SMALL TUBING LEADS TO A SAMPLE SELECTOR VALVE. A SAMPLE IS DRAWN THROUGH A COMPARTMENT FILTER, THROUGH THE TUBING AND SELECTOR VALVE, AND INTO THE CENTRAL ANALYZER. INDIVIDUAL COMPARTMENTS CAN BE SAMPLED BY TURNING THE SAMPLE SELECTOR VAVLE TO THE APPROPRIATE POSITION. SAMPLES ENTER ALL THE CENTRAL ANALYZERS AT ATMOSPHERIC PRESSURE.

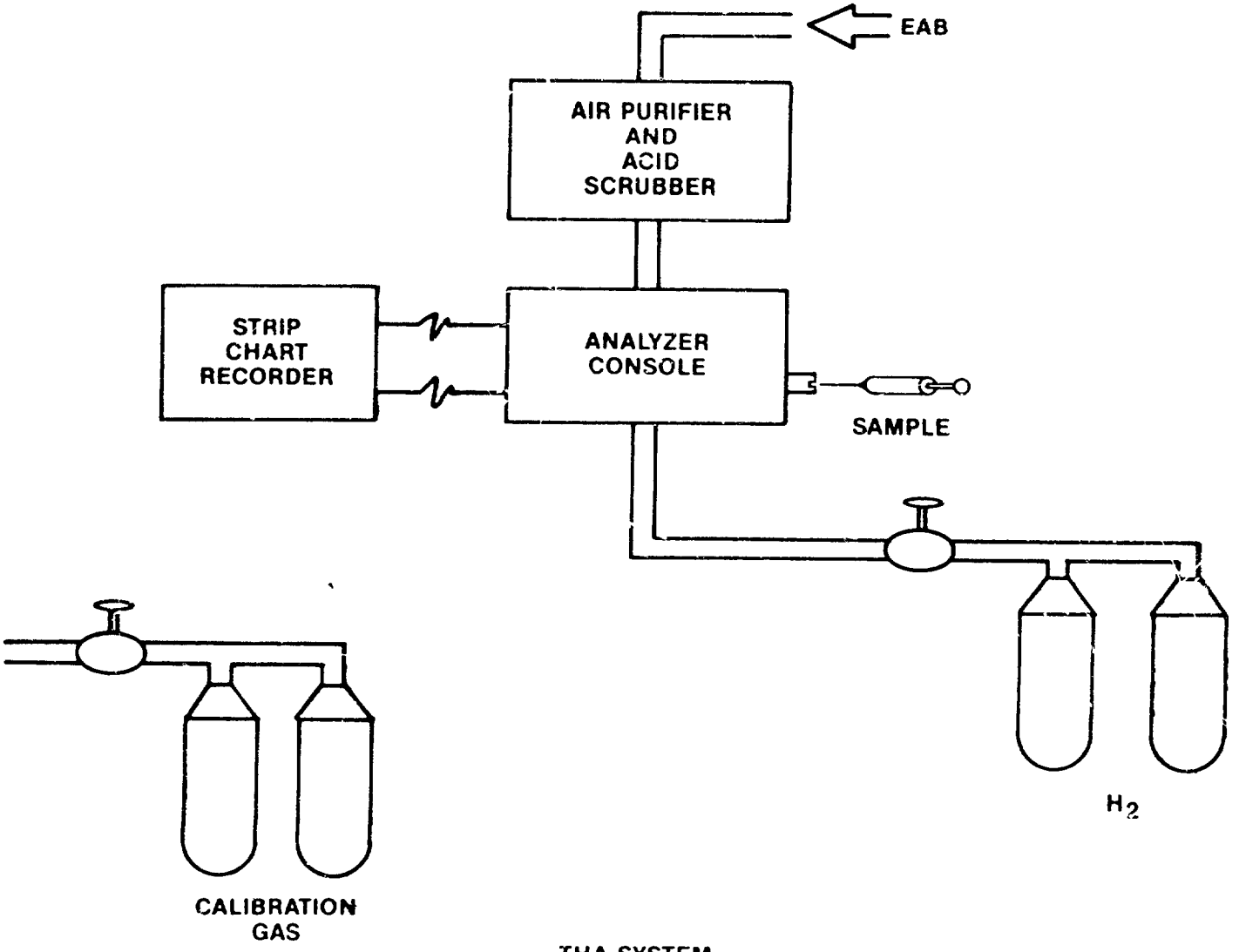


CENTRAL ATMOSPHERE MONITOR MK I

FUNCTIONAL BLOCK DIAGRAM

IN CAMS, GASEOUS SAMPLES ARE INTRODUCED INTO THE MASS SPECTROMETER THROUGH AN INLET SYSTEM WHICH REDUCES THE SAMPLE PRESSURE TO A LEVEL COMPATIBLE WITH THE ION-SOURCE OPERATING PRESSURE. THE SAMPLE IS SEPARATED AND SENT TO THE MASS SPECTROMETER PORTION OF THE INSTRUMENT. THE MAJOR PORTION OF THE INLET SAMPLE IS DIVERTED TO A NON-DISPERSIVE INFRARED ANALYZER WHICH EXAMINES THE SAMPLE FOR CARBON MONOXIDE.

THE CAMS PERFORMANCE HAS BEEN EXCELLENT. THE TWO MOST SIGNIFICANT PROBLEMS HAVE BEEN WITH THE CO ANALYZER AND THE INLET LEAK VALVE. OTHER PROBLEMS HAVE OCCURRED IN THE MASS SPECTROMETER POWER SUPPLY AND THE ION PUMP POWER SUPPLY. BOTH OF THESE POWER SUPPLIES HAVE MODIFICATION KITS WHICH CAN UPGRADE THE ANALYZERS TO PERFORM MORE SATISFACTORILY.



2-62

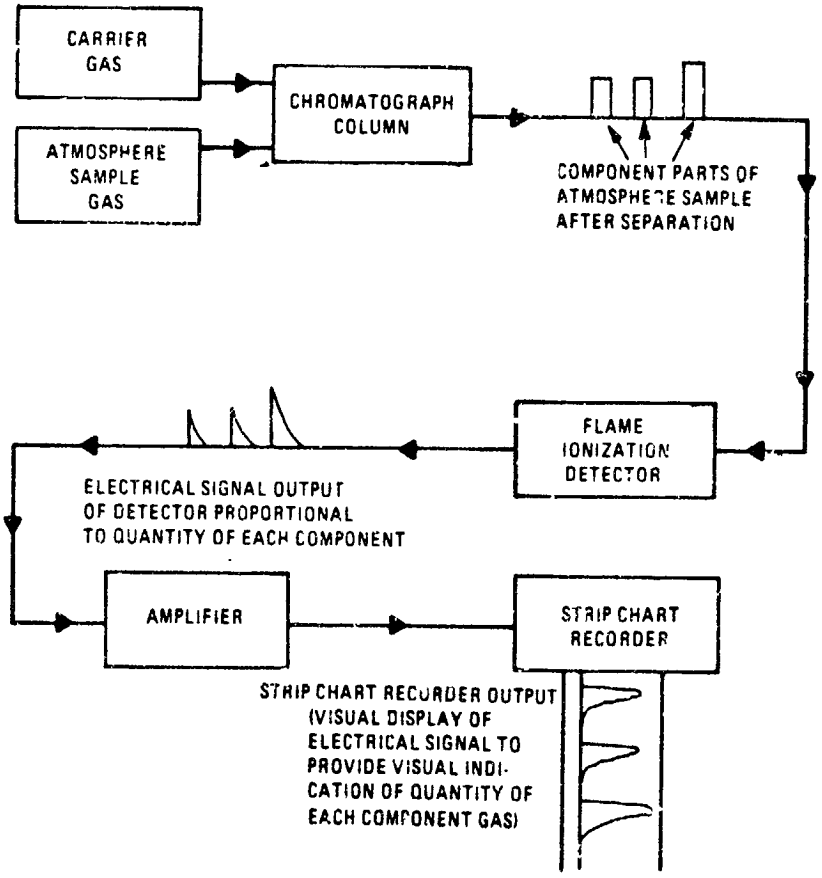
THA SYSTEM

VII. TOTAL HYDROCARBON ANALYZER

DURING SUBMERGED OPERATION, THE CLOSED ATMOSPHERE OF A SUBMARINE IS SUSCEPTIBLE TO A BUILDUP OF TOXIC AND A CORROSIVE GASES, A PORTION OF WHICH ARE HYDROCARBONS. EXAMPLES OF THE MORE COMMON HYDROCARBONS ARE METHANE (FROM CIGARETTE SMOKE AND THE SANITARY TANKS), BENZENE (FROM SOLVENTS, FUEL OIL, AND LUBE OIL), R-12 (FROM REFRIGERATION PLANTS) AND R-114 (FROM THE AIR CONDITIONING PLANTS). THE TOTAL HYDROCARBON ANALYZER (THA) MEASURES THE CONTAMINANT LEVELS OF SOME SPECIFIC HYDROCARBONS AND GROUPS THE HEAVIER HYDROCARBONS INTO A MEASURABLE QUANTITY.

THE TOTAL HYDROCARBON ANALYZER (THA) IS AN INSTRUMENT WHICH UTILIZES GAS CHROMATOGRAPHY TO INDICATE THE CONCENTRATIONS OF HYDROCARBON GASES. THE SYSTEMS CONSISTS OF AN ANLAYZER CONSOLE, WHICH SEPARATES AND MEASURES THE HYDROCARBON GASES; AN AIR PURIFIER AND ACID SCRUBBER ASSEMBLY, WHICH PURIFIES AIR FROM THE SHIP'S COMPRESSED AIR SYSTEM AND REMOVES ANY ACIDS WHICH MAY BE FORMED DURING THE PURIFICATION PROCESS; A STRIP CHART RECORDER, WHICH RECORDS THE INDICATED CONCENTRATIONS OF HYDROCARBON GASES; HYDROGEN CYLINDERS TO PROVIDE FUEL WHICH IS USED IN THE FLAME IONIZATION DETECTOR; TWO CALIBRATION GASES; AND A 100CC GLASS SYRINGE WHICH IS USED TO COLLECT GAS SAMPLES.

THE OPERATION OF THE ANALYZER CONSOLE, IN WHICH THE SEPARATION AND ANALYSIS OF A GAS SAMPLE OCCURS, IS FUNCTIONALLY DEPENDENT UPON THE SIMULTANEOUS OPERATION OF THE AIR



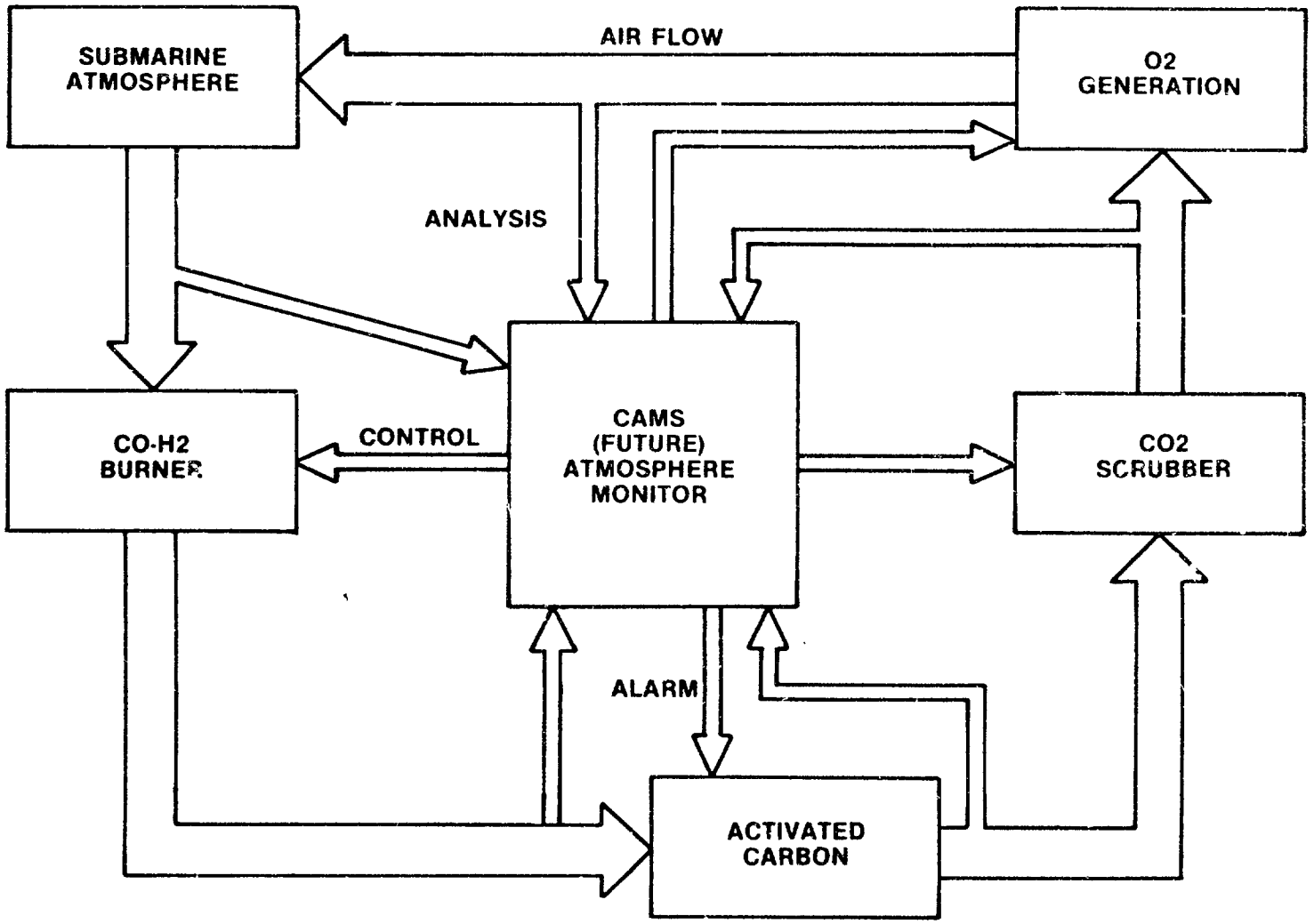
TOTAL HYDROCARBON ANALYZER

SIMPLIFIED DIAGRAM OF A GAS CHROMATOGRAMS

PURIFIER/ACID SCRUBBER. THE AIR PURIFIER/ACID SCRUBBER PROVIDES A PURE AIR SUPPLY FOR USE AS A CARRIER GAS (COLUMN AIR) AND FOR USE AS COMBUSTION AIR (FLAME AIR) USED IN THE FLAME IONIZATION DETECTOR.

THE AIR PURIFIER/ACID SCRUBBER RECEIVES AIR FROM THE EAB SYSTEM WHICH FLOWS THROUGH A HEATER AND INTO THE ACID SCRUBBER LIOH CARTIRDGE FOR REMOVAL OF ANY RESIDUAL ACIDS PRODUCED BY THE CHEMICAL REACTION OF CONTAMINANTS WITH THE AIR PURIFIER CATALYST. THE AIR, NOW FREE OF HYDROCARBON AND ACID CONTAMINANTS, FLOWS THROUGH THE AIR OUT PORT ON THE FRONT PANEL AND THROUGH THE CONNECTED HOSE TO THE AIR INLET PORT OF THE ANALYZER CONSOLE.

THIS IS WHERE THE ACTUAL BREAKDOWN AND ANLAYSIS OF GAS SAMPLES OCCURS. THERE, THE CHROMATOGRAPH COLUMN SEPARATES A MULTICOMPONENT GAS SAMPLE MIXTURE INTO ITS INDIVIDUAL COMPONENTS. A CONSTANT FLOW OF GAS, CALLED CARRIER OR COLUMN GAS, PASSES THROUGH THE COLUMN CONTINUOUSLY AND TRANSPORTS THE SAMPLE GAS THROUGH THE COLUMN. A PRECISELY MEASURED VOLUME OF THE SAMPLE GAS IS INTRODUCED INTO THE COLUMN. A FLAME IONIZATION DETECTOR, LOCATED AT THE OUTLET OF THE COLUMN, DETECTS THE CONCENTRATIONS OF THE SAMPLE GAS COMPONENTS AS THEY EMERGE FROM THE CHROMATOGRAPH COLUMN IN THE CARRIER GAS STREAM. THE ASSOCIATED ELECTRICAL SIGNAL GENERATED BY THIS PROCESS IS AMPLIFIED AND FED TO A STRIP CHART RECORDER. THE RECORDER PLOTS THE OUTPUT SIGNAL AGAINST TIME, AND THE RESULTING GRAPH IS CALLED A CHROMATOGRAM.



INTEGRATED LIFE SUPPORT MONITORING/CONTROL

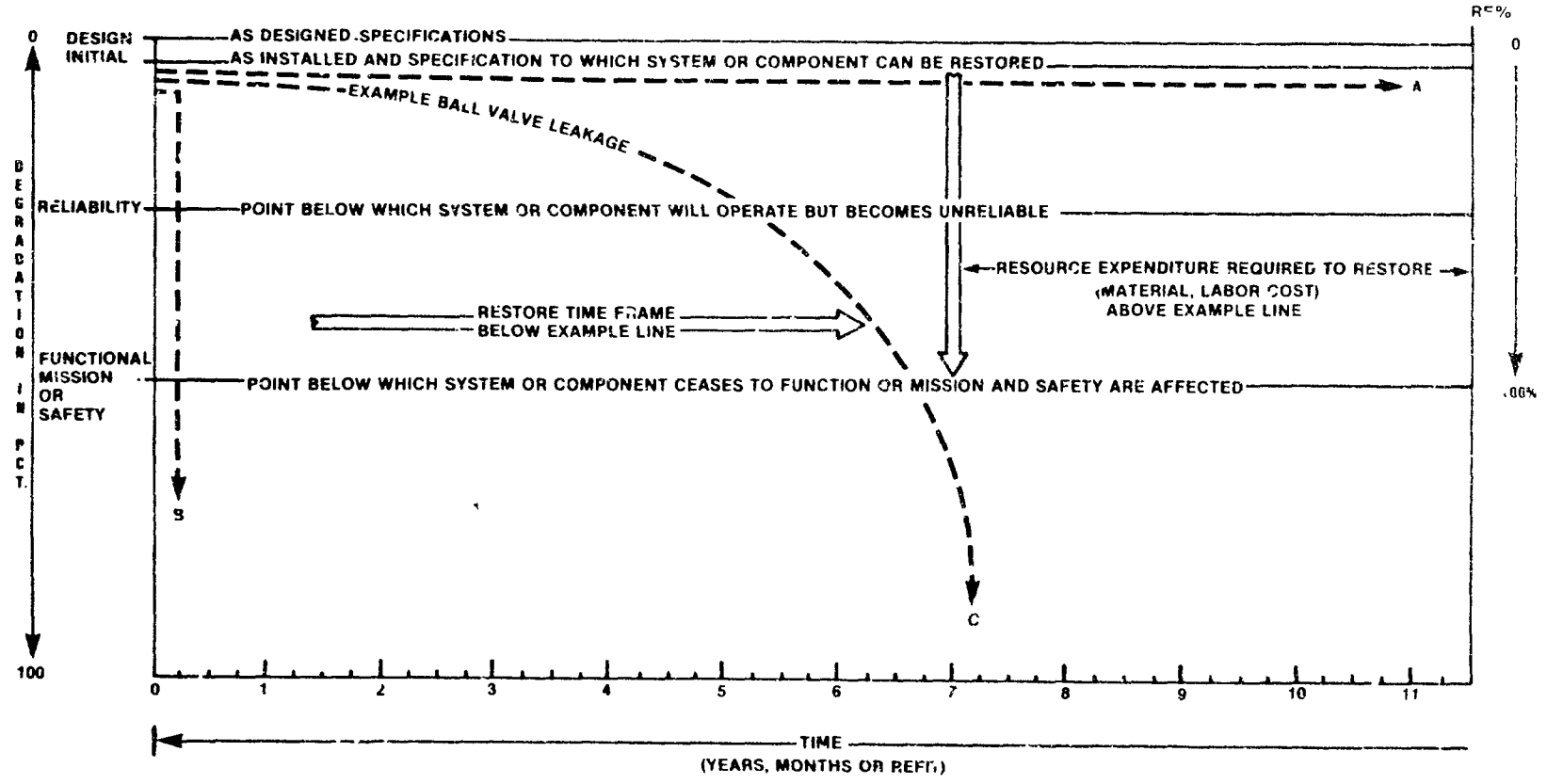
IX. INTEGRATED LIFE SUPPORT SYSTEM

AN IMPROVED CAMS HAS BEEN DEVELOPED, EVALUATED AND LABORATORY-TESTED AND IS SCHEDULED FOR QUALIFYING FOR SUBMARINE USE BY THE NAVAL RESEARCH LABORATORY AND PERKINS-ELMER CORP. THE NEW CAMS (TERMED MKII) CAN MONITOR MORE GASES, HAS A PROGRAMMABLE PROCESSOR THAT PERMITS THE SELECTION OF GASES TO BE MONITORED, AND HAS DATA-RECORDING CAPABILITIES.

THE EARLIER CAMS (MKI) IS A FIXED COLLECTOR MASS SPECTROMETER CAPABLE OF MONITORING ONLY EIGHT IONS OF PRE-SELECTED MASS TO CHARGE RATIOS.

NEW ENVIRONMENTAL CHANGES COULD REQUIRE THE NEED TO MONITOR NEW TYPES AND LEVELS OF CONTAMINANTS, THUS, A SCANNING MASS SPECTROMETER HAS BEEN DEVELOPED. THE USE OF THIS SOMEWHAT DELICATE INSTRUMENT IS NOW CONSIDERED FEASIBLE BECAUSE OF ADVANCED COMPUTER TECHNOLOGY AND INSTRUMENTATION PACKAGING. THE IMPROVED CAMS WILL MEASURE HYDROCARBONS (ELIMINATING THE NEED FOR THAS), HAVE THE CAPABILITY TO CONTINUOUSLY DISPLAY CONCENTRATION OF SELECTED GAS, ADD AND/OR DELETE CONTAMINANTS VIA COMPUTER SOFTWARE CHANGES, AND ACTIVATE AN ALARM SYST R OUT-OF-TOLERENCE CONDITIONS.

IF PROVEN SUCCESSFUL, MINOR MODIFICATIONS COULD ALLOW AN INTEGRATED LIFE SUPPORT SYSTEM WITH APPROPRIATE ALARMS AND CONTROLS.



RELATIONSHIP OF RELIABILITY MINIMUMS TO DEGRADATION RATE

X. PERFORMANCE MONITORING/CONDITION ASSESSMENT

MANY SUBMARINE LIFE SUPPORT SYSTEMS AND COMPONENTS HAVE THEIR OPERATING PERFORMANCE MEASURED, ANLAYZED FOR DEGRADATION TRENDS, AND ASSESSED FOR MATERIAL CONDITIONS IN ORDER TO CONDUCT MAINTENANCE ACTIONS PRIOR TO REACHING UNRELIABLE CONDITIONS.

THE PROCESS OF ESTABLISHING A PERFORMANCE MONITORING/MATERIAL ASSESSMENT PROGRAM INVOLVES THE SELECTION OF SYSTEMS AND COMPONENTS, THE PERFORMANCE AND MATERIAL CONDITION CRITERIA, INSPECTIONS AND MONITORING PROCEDURES, AND ANALYSIS AND ASSESSMENT TECHNIQUES. RELIABILITY MINIMUM VALUES NEED TO BE ESTABLISHED PRIOR TO ATTEMPTING TO DETERMINING WHETHER OR NOT THE PROPER PARAMETER CAN BE MEASURED TO ALLOW SOME REASONABLE TREND ANALYSIS AND PREDICTION FOR MAINTENANCE.

IN THE SAMPLE GRAPH, CURVE A INDICATES THE DEGRADATION RATE OF COMPONENTS WHERE LITTLE, OR NO MEASURABLE REDUCTION IN PERFORMANCE OR CONDITIONS IS EXPERIENCED OVER TIME. AT THE OTHER EXTREME, CURVE B SHOWS A COMPONENT SUBJECT TO INSTANTANEOUS FAILURE WITHOUT ANY PRIOR MEASURABLE DEGRADATION IN PERFORMANCE. RELIABILITY HAS NO REAL MEANING IN EITHER CASE. CURVE C ILLUSTRATES, AFTER SOME LEVEL OF DEGRADATION IS REACHED, THAT THE RATE OF DEGRADATION ACCELERATES RAPIDLY.

TOXICITY AND THE SMOKE PROBLEM: Harold L. Kaplan, Arthur F. Grand and Gordon E. Hartzell, Department of Fire Techology, Southwest Research Institute, San Antonio, TX 78284

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